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What do we know about the nutritional status of the very old? Insights from three cohorts of advanced age from the UK and New Zealand

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Very old people (referred to as those aged 85 years and over) are the fastest growing age segment of many Western societies owing to the steady rise of life expectancy and decrease in later life mortality. In the UK, there are now more than 1·5 million very old people (2·5 % of total population) and the number is projected to rise to 3·3 million or 5 % over the next 20 years. Reduced mobility and independence, financial constraints, higher rates of hospitalisation, chronic diseases and disabilities, changes in body composition, taste perception, digestion and absorption of food all potentially influence either nutrient intake or needs at this stage of life. The nutritional needs of the very old have been identified as a research priority by the British Nutrition Foundation's Task Force report, Healthy Ageing: The Role of Nutrition and Lifestyle. However, very little is known about the dietary habits and nutritional status of the very old. The Newcastle 85+ study, a cohort of more than 1000 85-year olds from the North East of England and the Life and Living in Advanced Age study (New Zealand), a bicultural cohort study of advanced ageing of more than 900 participants from the Bay of Plenty and Rotorua regions of New Zealand are two unique cohort studies of ageing, which aim to assess the spectrum of health in the very old as well as examine the associations of health trajectories and outcomes with biological, clinical and social factors as each cohort ages. The nutrition domain included in both studies will help to fill the evidence gap by identifying eating patterns, and measures of nutritional status associated with better, or worse, health and wellbeing. This review will explore some of this ongoing work.

Nutritional status: Aged 80 and over: Very old: Newcastle 85+: LiLACS

The European Commission's 2015 ageing reports that the percentage of those aged ⩾80 years in the total population in Europe will increase from 5 % in 2013 to 12 % in 2060(1). Over the next 20 years, the population of England and Wales will increase by almost 10 %; in comparison, older people in the over 85 years age group will increase by around two-thirds(2). In addition to the policy priority assigned to improving the healthcare of older

Abbreviations: 25(OH)D, 25-hydroxyvitamin D; BIA, bioelectrical impedance analysis; DP, dietary patterns; EPIC, European Prospective Investigation into Cancer and Nutrition; FFM, fat-free mass; FM, fat mass; LiLACS NZ, Life and Living in Advanced Age study (New Zealand); MPR, multiple pass recall; NDNS, National Diet and Nutrition Survey.
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people within westernised societies there is great scientific interest in studying the health of the very old and particular interest in the role of nutrition in maintaining health and ameliorating age-related decline. Advancing age brings about socioeconomic, lifestyle and biological changes. Social isolation, financial constraints, reduced mobility and independence, high incidence of frailty and chronic diseases, changes in body composition, sensory perception and absorption, tooth loss, polypharmacy and higher rates of hospitalisation all contribute to the risk of inadequate nutrient intake[3,4].

Food is a key contributor to enjoyment, health and wellbeing at all stages of the life-course and remains very important for physical, psychological and social wellbeing in the very old. The amount of physical activity undertaken in later life is a major determinant of energy needs, so that those who are least active, through frailty, disability or disease, are most at risk of nutrient deficiencies because of decreased food intake. Meeting the nutritional needs for some nutrients may be a particular challenge for those aged 85 years and over. For example, poor appetite[5] may lead to inadequate protein intake, which is a risk factor for the development of sarcopenia (loss of muscle mass and function) and, therefore, physical frailty[6]. Furthermore, age *per se* and some drugs which are used widely by the very old, have adverse effects on the sense of taste[7,8], on appetite[9] or on nutrient use by the body[10]. Dermal synthesis of vitamin D is reduced during ageing and by lack of exposure to sunshine (e.g. for those who are housebound) and low vitamin D status contributes to the risk of mortality[11], cognitive decline[12], several age-related diseases and low mood and depression[13]. Vitamin B_{12} uptake from the gut is impaired in those with atrophic gastritis (a common problem in older people[14] and vitamin B_{12} deficiency can damage the nervous system leading to balance disturbances and, possibly, more rapid cognitive decline. However, a recent intervention study (B-PROOF study) reported no effect of a combined supplement of folic acid and vitamin B_{12} on cognitive outcomes among older (mean age 74·1 years) Dutch participants[15]. These factors contribute to the heterogeneity in individual nutrient needs and to the complexity in translating guidelines for the nutritional needs of the oldest in the community into practical recommendations. Until recently there has been a dearth of data exploring the nutritional status of very old adults. Herein, this review will explore emerging data on nutritional intake and status and relationships to health in three unique cohorts of very old participants from the UK and New Zealand.

UK and New Zealand cohort studies of health and ageing in advanced age

UK: the Newcastle 85+ study

The Newcastle 85+ study is a longitudinal population-based study of health trajectories and outcomes of people aged 85 in 2006 (born in 1921) and who were registered with participating general practices within Newcastle upon Tyne or North Tyneside primary care trusts (North East England). The recruited cohort was sociodemographically representative of England and Wales and included institutionalised and cognitively impaired very old adults[16]. The study received ethical approval from the Newcastle and North Tyneside 1 Research Ethics Committee (06/Q0905/2). Written informed consent was obtained from participants and where these were unable to do so, one was obtained from a carer or a relative. Participants were able to decline any element of the protocol. General practices that took part in the Newcastle 85+ study were similar to those that did not in practice size, training practice status, index of multiple deprivation, NHS quality and outcomes framework score[17]. Participation in the study entailed a detailed multidimensional health assessment (questionnaires, fasting blood sample, measurements and function tests) carried out by a research nurse at each participant's usual residency; and a review of general practice records done at baseline and every 18 months until 60 months. Participants were thereafter followed for date and cause of death. Of the 1409 people approached (nearly all the 85 years old population in this area), 358 declined and nine were neither able to give informed consent nor a relative or carer was available. Of the 1042 recruited, 845 participants had complete health assessment and general practice records review at baseline (2006–2007)[17], 631 at phase 2 (general practice records not reviewed in this phase; 18 months from baseline), 484 at phase 3 (36 months from baseline) and 344 at phase 4 (60 months from baseline)[18]. Deprivation did not differ significantly between refusers, record review only participants and those that had health assessment plus record review, but fewer females were in the full health assessment group than in others[16]. Further details on the Newcastle 85+ study are reported elsewhere[16–18] (for study questionnaires visit http://research.ncl.ac.uk/85plus).

New Zealand: Life and Living in Advanced Age study (the LiLACS study): a cohort study in New Zealand-e Puāwaitanga o Nga Tapuwae Kia Ora Tonu

The Life and Living in Advanced Age study in New Zealand (LiLACS NZ) is a bicultural cohort study of advanced ageing and recruited 937 participants from the Bay of Plenty and Rotorua regions of New Zealand in 2010, 421 Māori born in 1920–1930 (aged 80–90 years, 56 % of those eligible) and 516 non-Māori born in 1925 (aged 85 years, 59 % of those eligible)[19–24]. For the Māori cohort, participant gender and age distribution was roughly representative, while non-Māori women were slightly underrepresented. The bicultural study required adequate cultural support and oversight. Māori cultural oversight was provided by a Ropūkiatiaki group (cultural governance group) along with translation support for the interview. The project was co-led by Māori; Māori coordinators, interviewers and nurses which were fluent in te reo Māori; and all processes were reviewed regularly for appropriateness for Māori participants. Written informed consent was obtained from participants, and trained interviewers completed multidimensional interviews and trained research nurses completed physical assessments. Sociodemographic and personal history included tribal affiliation for Māori and participation in cultural practices; physical and psychological assessment used standardised validated research tools; health behaviours included questionnaires on smoking frequency, alcohol use and nutritional risk; and environmental data included local amenities, type of housing and neighbourhood. Social network structures and social support exchanges were recorded. Measures of physical function; gait speed, leg strength and balance, were completed. Questionnaires on everyday interests and activities, views on ageing and financial interests were also part of the interview. Physical assessment was carried out by a trained nurse and included electrocardiograph, blood pressure, hearing and vision, anthropometric measures, respiratory function testing and blood samples[25]. In the first year of follow-up 660 were reinterviewed, 48 months follow-up was completed by 534 and 438 completed the 36 months follow-up. To date, 5 years (60 months) of follow-up have been completed. In the 12-month follow-up interview, a detailed dietary intake assessment was completed (2 × 24 h multiple pass recall (MPR)), from the 24-month follow-up onwards, carers were engaged and interviewed in the kaiawhina study and questions about end of life preferences were included. Further information is available including preliminary results[19–24] some of which will be described in this review.

Dietary assessment in the very old

Collection of robust data on dietary intake is key to understanding nutrition-related outcomes with the usual aim being to collect a true record of the habitual food intake of an individual or group of individuals. Dietary assessment at any life stage presents challenges. Progress in the development of biomarkers may mean that, in the future, such questions can be addressed by collection and analysis of biological samples[26], but meanwhile dietary assessment remains labour intensive and therefore costly. The methods at our disposal include weighed dietary intakes; estimated weight food diaries; food records and FFQ each requiring varying levels of commitment, time and cognitive ability from the respondent and time and skill of the researcher as well as having differing demands on researcher time and therefore cost. The method of choice must be driven by the question to be answered but also, and with equal importance, by the population group to be assessed. Assessing food choice and/or nutrient intake in older people, particularly the very old (85 years and over), presents particular challenges. In some cases, the respondent may have little or no involvement in food purchasing or preparation, in others, cognitive/memory impairment may restrict ability to recall intake; ability to record intake may be limited by physical limitations imposed by age as well as by sensory impairment and communication difficulties. Reporting may need to rely on a carer as a proxy reporter which may then be compounded by the fact that a number of individuals or carers may be involved in the care of the respondent on any given day.

Given the challenges it is perhaps not surprising that data on the dietary intake of the very old are scarce. The UK National Diet and Nutrition Survey (NDNS) of people aged 65 years and over[27] included dietary data collected by 7 d weighed intakes from only 459 people aged 85 years and over. At the time of planning for the Newcastle 85+ study no retrospective methods of dietary assessment had been used previously in this age group in the UK. At that time all NDNS surveys had used either 4 or 7 d weighed dietary intakes; this prospective method is very resource intensive and imposes a large burden on subjects. We sought a retrospective method which would require no recording of intake by participants. At the same time a review of NDNS surveys showed that those of lower socio-economic status and minority ethnic groups were underrepresented[28]. Therefore an NDNS of those living on a low income was planned and the most appropriate method to collect dietary data from these subjects sought. As a result, the repeated (×4) 24 h MPR method was used in the Low Income National Diet and Nutrition Survey[29]. The MPR had been developed and used extensively for national surveys by the US Department of Agriculture but had not been used previously in national surveys in the UK.

We applied the 24 h MPR dietary assessment method in the Newcastle 85+ (UK) and LiLACS study (NZ). This dietary assessment method was completed successfully on a large number of people with advanced age in three cohorts in two countries thus yielding detailed data on dietary intake of diverse groups of octogenarians. The Newcastle 85+ study (UK) recruited people aged 85 years during 2006–2007. The 24 h MPR×2 days was conducted by trained assessors. LiLACS NZ recruited Māori aged 80–90 and non-Māori aged 85 years in 2010 with adaptation of pictorial resources and language used in Newcastle MPR for the NZ and Māori contexts.

In the Newcastle 85+ study, 805 (95 %) consented to the MPR, with 793 (99 %) completing two 24 h MPR; in LiLACS NZ, 579 (82 % of Māori and 92 % of non-Māori) consented and 203 (93 %) Māori and 353 (98 %) non-Māori completed two 24 h MPR. Mean time to complete a single 24 h MPR was 22 min (Newcastle 85+ study), 45 min (LiLACS NZ Māori) and 39 min (LiLACS NZ non-Māori). Dietary assessment of participants in residential care and those requiring proxy respondents were included successfully in both studies. In both studies, 77–88 % and 81–94 % of the participants that answered the 24 h MPR on day 1, and 84–94 % and 86–96 % of those that answered on day 2 believed that it reflected their usual food and drink intake, respectively (A Adamson, K Davies, C Wham *et al.*, unpublished results). This method was successful in capturing detailed dietary data, including information on portion size and time of eating, for over 1300 octogenarians in the UK and NZ. There were, however, some difficulties reported with the method, particularly related to some participants having poor memory of foods consumed and being embarrassed by the detailed inquiry. Social desirability bias[30,31] could result in participants underreporting food groups they believe are unhealthy and over-reporting those believed to be healthy.

Any self-reported health behaviour is open to social desirability bias and the skill of the interviewer in putting the participant at ease is important to minimise such bias. Sound training, including the rationale for the detail needed in recording of food intake (e.g. brand names), is necessary to enable interviewers to effectively address sociability bias.

Advantages of 24 h MPR include: minimal respondent burden compared with prospective methods (weighed or unweighed food diaries), ability to be completed by an interviewer[32], and the conversational nature of process when compared with other methods. The 24 h MPR provides detailed information on the specific foods eaten, it requires only short-term memory and minimises participant burden[33]. Disadvantages include: a reliance on recall and memory, portion size estimation, and being resource heavy in terms of requiring trained interviewers and data preparation. Nonetheless, 24 h MPR has been shown to be more acceptable and accurate than FFQ in this age group[34] with the added advantage of providing estimates of amounts consumed and time of intake without the participant burden of prospective recording. The 24 h MPR method allows the analyses of dietary patterns (DP) and nutrient intakes and so facilitates examination of the influence of diet on health and well-being outcomes. Of currently available options, 24 h MPR is an acceptable, and potentially preferred method, of dietary assessment in this age group.

Dietary intake in the very old

Only a small number of population-based studies focusing on nutrition included the very old. The NDNS of people aged 65 years old and over was carried out during 1994–1995 in the UK and included two nationally representative samples drawn from adults aged 65 and over, free-living and institutionalised. Health background questionnaires, 4-d weighed diet record and blood/urine samples were collected. A total of 459 free-living adults (172 men and 287 women) aged 85 and over completed the 4-d weighed diet record[27]. The European Prospective Investigation into Cancer and Nutrition (EPIC)-Oxford study is a prospective cohort study that started in 1993 in Oxford, UK and was designed to investigate how diet influences the risk of cancer. A FFQ, lifestyle questionnaire and blood samples were collected. By the time of the third follow-up in 2010–2014, 1283 adults (411 men and 872 women) aged 80 and over had completed the FFQ[35]. The Dutch National Food Consumption Survey of free-living older adults was carried out in the Netherlands in 2010–2012 and included one nationally representative sample of adults ⩾70 years old. Two 24-h recalls, anthropometric measures and background questionnaires were collected. In the Dutch National Food Consumption Survey of free-living older adults, 225 adults ⩾80 years (103 men and 122 women) completed both 24-h recalls[36]. The InCHIANTI (Ageing in Chianti) study was conducted in 1998 in Tuscany, Italy and included people aged 21–103 years old. Data were collected on dietary intakes (FFQ), sociodemographic, lifestyle and functional characteristics. Of the total 1436 that completed the FFQ, 170 (sixty men and 113 women) were aged 85 and over[37]. A nationally representative study by Volkert *et al.* on behalf of the German Ministry of Health was conducted in Germany in 1998 to describe the energy and nutrient intakes of older free-living adults. Sociodemographic, lifestyle and dietary assessment (3-d dietary record) were collected. A total of 287 adults ⩾85 years (89 men and 198 women) had complete dietary records for the 3 d[38]. The 2003 Austrian Nutrition Survey collected dietary data, using 3-d food records, on ⩾85 and included 22 men and 93 women[39]. In the Newcastle 85+ study at baseline (2006/2007), complete dietary intake data (without protocol violation) assessed by the repeated MPR (2 × 24 h recalls) were available for 793 participants (A Adamson, K Davies, C Wham *et al.*, unpublished results).

Comparison of nutrient intakes between these studies should be done cautiously as the dietary assessment methods, data collection period, sample size, food composition tables used and nutrient definitions are seldom the same. Of the seven European studies with considerable numbers of ⩾80 or 85 older adults, two used 24 h recalls, two used FFQ and three used different forms of diet records. EPIC-Oxford had the largest number of ⩾80 (*n* 1283) but the Newcastle 85+ study had 793 participants 85 years old at baseline. The energy and selected nutrient intakes in European very old adults (⩾80 or 85) is shown in Table 1. Men and women of the German Nutrition Survey and EPIC-Oxford had the highest energy intakes (above 9·25 for men and 8·0 MJ for women). In the Newcastle 85+ study, median daily energy intakes were 7·73 MJ in men and 6·15 MJ in women, while 46·8 % (both genders) was from carbohydrates, 36·4 % (men) and 37·2 % (women) from total fat and, 15·9 % (men) and 15·5 % (women) from protein[40]. In all the studies, carbohydrates contributed to energy intake with 41–50 %, fat with 31–40 % and protein with 14–16 %. Dietary fibre intake varied considerably between country and study and depended largely on the dietary assessment method (FFQ *v.* 24 h recall) and analysis method (Englyst or AOAC). NSP intake was 10·2 g/d in the Newcastle 85+ study[40]. Vitamin and mineral intakes in EPIC-Oxford were generally higher than in any other study but the choice of dietary assessment method and participants' age have to be taken into account. The very old adults participating in the Dutch National Food Consumption Survey had higher intakes of vitamin B_{12} and calcium than others (except EPIC-Oxford) which reflects the high dairy products consumption[36]. In the Newcastle 85+ study, < 40 and 25 % of participants met the reference nutrient intake for all minerals (except sodium) and all vitamins (except vitamin B_{12}), respectively, µg/d[41]. More than 95 % (*n* 37) were below the reference nutrient intake for vitamin D, while 20 % or more were below the lower reference nutrient intake for magnesium (*n* 175), potassium (*n* 238) and selenium (*n* 418)[41].

Dietary patterns and health in the very old

Instead of concentrating on one single nutrient or food group when testing diet-disease hypothesis (a single nutrient/food approach), recent developments in nutritional

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Table 1. Energy and nutrient intakes in European very old adults

Nutrients study	Men										Women									
	Energy (MJ/d)	Carb (%)	Fat (%)	Protein (%)	Fibre (g/d)	Folate (µg/d)	B_{12} (µg/d)	D µ(g/d)	Ca m(g/d)	Iron (mg/d)	Energy (MJ/d)	Carb (%)	Fat (%)	Protein (%)	Fibre (g/d)	Folate (µg/d)	B_{12} (µg/d)	D (µg/d)	Ca (mg/d)	Iron (mg/d)
NDNS[27]	6·99†	48·5	36·3	15·2	11·4‡	219	3·8	2·8	717	9·7	5·60	48·4	36·8	14·5	9·4†	170	2·9	2·0	619	7·5
EPIC*[35]	9·84	49·7	31·4	15·5	24·5‡	466	7·5	4·2	1157	18·1	9·02	50·3	31·5	16·3	24·0†	461	7·5	4·0	1147	17·0
DNFCS[36]	7·40	41·4	34·0	16·4	20·0	46§	4·9	3·9	1016	9·6	7·30	41·0	35·0	15·6	16·2	34§	4·4	2·9	2030	8·3
InCHIANTI*[37]	7·38	50·0	29·0	16·0	17·2	228	–	–	778	11·5	6·36	50·0	32·0	16·0	15·3	200	–	–	701	9·6
German Nutrition Survey[38]	9·34	44·2	33·2	16·3	23·7	123‖	–	3·8	721	13·3	8·07	42·6	35·0	16·2	19·9	106‖	–	2·7	729	12·6
Austrian Nutrition Survey*[39]	7·40	44·0	40·0	14·0	15·0	174‖	4·0	3·4	642	10·0	7·10	43·0	40·0	16·0	16·0	166‖	3·9	3·1	649	11·1
Newcastle 85+[40,41]	7·73†	46·8	36·4	15·9	11·3†	245	3·4	2·3	829	10·5	6·15	46·8	37·2	15·5	9·3†	189	2·6	1·8	683	7·8

NDNS, National Diet and Nutrition Survey; EPIC, European Prospective Investigation into Cancer and Nutrition; DNFCS, Dutch National Food Consumption Survey; InCHIANTI, Ageing in Chianti; Carb, carbohydrates; B_{12}, vitamin B_{12}; D, vitamin D; Ca, calcium.
Values are medians unless stated otherwise.
* Values are means.
† Does not include alcohol.
‡ NSP.
§ Only folic acid.
‖ Dietary folate equivalents (1 µg DFE = 1 µg food folate = 0·5 µg folic acid supplement on empty stomach = 0·6 µg folic acid from fortified food or as a supplement taken with meals).

epidemiology advocate the importance of whole diet, DP and consequent interaction of foods and nutrients (a whole diet/DP approach) on health outcomes in general and older adults population[42–45]. Healthy DP defined either by a greater adherence to predefined dietary scores (e.g. Mediterranean-style diet) and dietary approaches to stop hypertension) or established through statistical techniques (e.g. cluster analysis) have been linked to reduced risk of common age-related diseases (e.g. CVD, stoke and dementia)[46–49] and mortality[50,51]. Compared with less healthy DP, healthy DP are characterised by higher intake of beneficial foods (e.g. whole grains, fish, lean meat, fruit and vegetables, nuts, low-fat dairy and olive oil) and their combination, which results in diets dense in essential nutrients but low in energy from nutrient-poor foods (e.g. refined grains, sweets and sources of saturated fats)[52,53].

DP analysis offers several advantages in exploring the link between diet and health by (a) capturing the complexity of human diet; (b) accounting for additive, cumulative, synergistic and antagonistic effects of foods and nutrients on health outcomes, whilst (c) acting as a single exposure[42,54,55]. Two main approaches to derive DP have been used in the literature: *a priori* and *a posteriori* approach. Whereas either assesses usual diet, both have strengths and limitations. *A priori* (more frequently used) approach is hypothesis-driven, and calculates the level of adherence to a pre-defined dietary index for a specific diet (e.g. Mediterranean-style diet and dietary approaches to stop hypertension) or dietary guidelines for healthy diet (e.g. healthy eating index and recommended food score). Weaknesses of this approach include: (a) the dependence on current scientific understanding of what represents a healthy diet (which may not meet the nutritional requirements of very old adults) and (b) inability to account for a whole diet and its effect on health[54,55]. Conversely, *a posteriori* approach is exploratory, data-driven and not reliant on prior hypotheses about diet quality and health. *A posteriori* approach uses all available dietary data of a specific population to derived DP, and may therefore better describe the habitual diet. However, it depends on statistical methodology (i.e. data reduction techniques) employed to define DP such as factor and clustering analysis. Strengths of cluster over factor analysis include creation of homogenous, non-overlapping clusters based on likenesses in food and nutrient intake. While an individual can belong to more than one factor in factor analysis-derived DP, in clustering the individual is assigned to only one cluster (DP)[42,54].

There is limited evidence on diet and DP, and determinants of dietary habits in very old adults (aged 85 and over), despite common understanding of the potential benefits of higher diet quality on health and functioning across the life span. Also, very little is known about relationship between diet/DP and health and bio-psycho-social factors in this age group. Specifically, diet quality has been linked to socioeconomic status defined either by education, social class (occupation) and income in general and older adults populations (aged 60 and over)[56–58], but to which extent and which dimension socioeconomic status plays a role in diet characteristics in very late life is not known.

Utilising dietary data collected by 24-h multiple-pass dietary recalls from participants in the Newcastle 85+ study[16,17,34] and two-step clustering, we identified three distinct DP, which differed with respect to the key sociodemographic, lifestyle, health and functioning measures[59]. 'High Red Meat' DP had the highest proportion of participants (and the highest mean intake (g/d)) consuming red and processed meats/meat dishes, potato/potato dishes, gravy, legumes (including baked beans) and unsaturated fats spreads, but the lowest consumption of butter. Participants in this DP had the highest per cent energy from protein and starch, and were the most likely to be diagnosed with CVD. Those in the 'Low Meat' DP had lower consumption of meats, gravy and potato, moderate consumption of butter, but had the highest consumption of fruits, nuts, whole grains, fish, eggs, soups, dairy, coffee and alcohol. Based on foods, nutrients and blood lipids characteristics, this DP was regarded as the healthiest. Participants in this DP were more advantaged compared with others: had higher education, social class, owned their homes, and lived in more affluent areas. They were also healthier: less disabled, depressed, obese, cognitively impaired and diagnosed with dementia at baseline. The 'High Butter' DP was the highest in butter, moderate in red meats and low in other saturated and unsaturated fat spreads and oils. Participants in this DP had the highest total fat, cholesterol, MUFA and SFA, and the lowest PUFA and MUFA: SFA ratio. They also had the highest per cent energy from fat and SFA, and the highest food energy density. Lower educational attainment predicted the membership of the less favourable 'High Red Meat' and 'High Butter' DP regardless of other socioeconomic status measures (i.e. social class and level of poverty in current area of residency), lifestyle, health-related factors and type of residence (i.e. living in institution or not)[59]. This is to confirm that higher education offers lifelong health benefits, which span beyond economic advantages but relate to individual's access to health information, healthier lifestyle and sense of control over one's life[60]. Future studies are underway to determine the role of DP in cognitive and physical functioning in this cohort.

Nutritional biomarkers in the very old: insights from the Newcastle 85+ study

Often the threshold for nutritional deficiency in very old adults is extrapolated from younger populations and may not be relevant for the very old. It is possible that vitamin requirements change as energy requirements do but without reliable nutritional intake and status data such specific biochemical indices cannot be set. In the Newcastle 85+ study, blood samples were taken after an overnight fast at baseline. Roughly 40 ml blood was drawn from the antecubital vein between 07.00 and 10.30 hours and 95 % of the samples were taken to the laboratory within 1 h. Blood samples were available for 719–778 participants (depending on the assay) at baseline but are also available at other time points. Nutritional biomarkers such as vitamin B_2, B_6, B_{12}, C, D, ferritin, red blood folate and homocysteine were measured[61].

Vitamin D status

Serum concentrations of 25-hydroxyvitamin D (25(OH)D) were analysed in 775 participants in the baseline phase of the Newcastle 85+ cohort study. Median serum 25(OH)D concentrations were 27, 45, 43 and 33 nM/l during Spring, Summer, Autumn and Winter, respectively[62]. The prevalence of vitamin D deficiency according to North American Institute of Medicine guidelines (serum 25(OH)D <30 nM/l) varied significantly with season with the highest prevalence observed in Spring (51 %) and the lowest prevalence observed in Autumn (23 %; $P < 0{\cdot}001$). In multivariate ordinal regression models, non-users of either prescribed or non-prescribed vitamin D preparations and winter and spring blood sampling were associated with lower 25(OH)D concentrations. Dietary vitamin D intake, disability score and disease count were not independently associated with vitamin D status in the cohort[62]. Data on the vitamin D status of the very old are scarce. In a cross-sectional investigation of 25(OH)D concentrations among 367 Belgian 80+ year olds, 20 and 66 % had serum 25 (OH)D concentrations <25 and 50 nM/l, respectively[63]. In a recent osteoporosis, screening trial investigating the anti-fracture efficacy of a new anti-osteoporotic drug, 25 (OH)D concentrations were measured at baseline in 1894 individuals aged 80+ years from nine different European countries[64]. Mean 25(OH)D concentrations were 53·3 (SD 26·7) nM/l in the entire cohort while serum 25(OH)D concentrations showed wide geographical variation with the lowest mean 25(OH)D concentration (45·7 nM/l) in Belgian participants and the highest mean concentration (81·7 nM/l) in Spanish participants[64]. The British participants in the Bruyere *et al.* study[64] (region not specified) had a mean 25(OH)D concentration of 61·8 nM/l with 22 % of the participants having 25(OH)D concentrations <50 nM/l. These 25(OH)D concentrations are considerably higher than those observed in Newcastle 85+ participants despite the fact that both studies used the same analytical assay for 25(OH)D (DiaSorin RIA). While no information was available on season from the European study[64], the use of non-prescribed vitamin D containing supplements was high at >30 % among the British participants[64] and higher than in Newcastle 85+ participants (19 %), which agrees with the evidence that vitamin D supplements have a significant effect on circulating 25(OH)D in older adults[65].

B-vitamin status

Erythrocyte folate and plasma vitamin B_{12} were analysed in 752 and 753 participants, respectively in the Newcastle 85+ study at baseline. The median (interquartile range) erythrocyte folate was 863 nM/l (451–1287) and only 3·6 % (*n* 26) were below the threshold of 340 nM/l (N Mendonça *et al.*, unpublished results). This is considerably lower than 30 % of free-living very old men and 34 % of free-living very old women (aged 85 and over) in the 1994–1995 NDNS below 345 nM/l of erythrocyte folate[27]. Nearly 4 % of erythrocyte folate deficiency in this population is also lower than the latest estimate of the NDNS rolling programme of 7·3 % men and 10·8 % women (aged 65 and over) below 340 nM/l of erythrocyte folate[66]. The median (interquartile range) plasma vitamin B_{12} was 232 (170–324). Roughly 17 % (*n* 125) were below the threshold of 148 pM/l for plasma vitamin B_{12} and, 15·0 % (*n* 110) were above 15 μM/l for homocysteine while being deficient for cobalamin (N Mendonça *et al.*, unpublished results). The NDNS rolling programme estimated that 5·9 % were below 150 pM/l of serum vitamin B_{12}[66]. Age and essay differences are likely explanations for the observed differences between the Newcastle 85+ study and the NDNS. The novel method used to assess erythrocyte folate in the NDNS rolling programme (whole blood folate by a microbiological assay, serum total folate by LC-MS/MS and haematocrit) is likely to give higher estimates of folate deficiency than the one used in the Newcastle 85+ study (Microparticle immunoassay on Abbott ARCHITECT analyser). The methods used for plasma vitamin B_{12} analysis are more comparable as both used similar methods (the NDNS used a competitive immunoassay with direct chemiluminescence (ADVIA Centaur B_{12} assay) and our study used the same method as used for erythrocyte folate).

Body composition in the very old

Ageing is associated with gradual modifications of body composition including increased abdominal adiposity and reciprocal changes in fat mass (FM) and lean body mass[67]. The rate and extent of these modifications are influenced by physiological and/or pathological factors influencing accretion or mobilisation of tissues such as menopause, insulin resistance, inflammation, mitochondrial efficiency and oxidative stress[67]. These modifications occur independently of changes in body weight, which explain the poor accuracy of BMI as a predictor of disease risk in older individuals[68]. Body composition methods, such as bioelectrical impedance analysis (BIA) or dual X-ray absorptiometry, provide an accurate assessment of body components for a more sensitive prediction of disease risk across the life course[68]. Body composition research in older individuals has primarily focused on the negative effects of excess adiposity, whereas the role of low lean body mass (i.e. sarcopenia) as an independent risk factor has often been overlooked[69]. In addition, limited information is currently available on the role of body composition for disease risk prediction in the very old. A consistent finding though has been the age-dependency of the association between adiposity with disease and mortality risk, as a lack of association or even reverse association has been observed in older subjects, particularly in the very old[70–72]. This inverted association may be explained by a ‘disease hypothesis’ which suggests that the decline in body fat may be a reflection of coexisting diseases and related treatments, which may be causally linked to the declined fat stores and, therefore, may act as confounding factors in the association between adiposity and disease risk.

The Newcastle 85+ study is one of the few population-representative cohort studies able to investigate the association between body composition measurements with all-cause mortality and disability in the very old[16,17]. Body composition was assessed by BIA at baseline and after a 3-year follow-up and detailed analyses have been conducted to test the association of body composition variables with prospective risk for cognitive decline, physical disability and overall mortality. BIA is a user-friendly method, which is widely used in clinical and research settings[68]. The theoretical principles of the BIA are based on the assumption of a constant hydration of fat-free mass (FFM) to estimate body components such as FM, FFM and total body water[68]. However, these assumptions have not been tested in the very old and whether shifts in hydration status may have an effect on the reliability of the BIA. We used the data from the Newcastle 85+ study to evaluate for the first time the influence of serum osmolarity, as a measure of whole-body hydration, on BIA-derived parameters. The analyses showed that the association between BMI and impedance was not modified by differences in serum osmolarity, which suggested that BIA measurements were unaffected by hydration status in this population[4]. Subsequent analyses evaluated the association between of anthropometric and body composition variables with disease risk. First, we evaluated whether baseline BMI and waist circumference were significant predictors of cognitive decline after 5 years. Both measures showed a non-significant association with risk of cognitive decline even when they were included within a diagnosis of metabolic syndrome[73]. We then tested whether these two anthropometric variables (and hip circumference) were significant predictors of physical disability and mortality[74]. We confirmed the non-significant association of BMI and waist circumference, whereas a greater hip circumference was associated with a decreased risk of mortality. The analysis of the BIA data generated some interesting results[74]. First, we found an unexpected lack of association between lean body mass with both physical disability and mortality[74]. On the contrary, we observed an interactive association between FM and FM:FFM ratio with prospective risk of disability and mortality. Specifically, while a higher adiposity was associated with an increased risk of disability, this risk was offset by a reduced overall mortality[74].

More analyses of the body composition dataset are underway and one of our main aims is to characterise the predictive role of pre-defined body composition phenotypes such as cachexia or sarcopenic obesity[69]. However, the limitation of the BIA method has been recognised and we believe that there is an urgent need for a validation study testing the accuracy of body composition methods, which could also provide the opportunity to characterise a healthy body composition phenotype in the very old. Our preliminary results support the application of detailed body composition methods for disease risk prediction in this age group since anthropometric measurements are poor indicators for the assessment of nutritional status and disease risk prediction in the very old.

Nutritional needs of very old people

Current challenges

The nutritional needs of the very old are very poorly understood. No specific nutritional guidelines for people aged 85+ years are provided by major national authorities in the UK, USA or Australia or by the EU (through the European Food Safety Authority). The Food and Nutrition Board, Institute of Medicine in the USA and the Scientific Advisory Committee on Nutrition in the UK offer recommendations for those aged 70+ years and 75+ years, respectively[75]. However, to a large extent, these recommendations are based on evidence from younger adults with unknown relevance for the very old.

Those aged 85+ years are a very diverse section of the population ranging from relatively healthy, active individuals to very frail individuals with multiple diseases and disabilities[16]. Multi-morbidity is the norm among the very old. In the baseline assessment of 851 participants in Newcastle 85+ study, none was disease free and the median and maximum number of diseases per individual were five and eleven, respectively[73]. This diversity creates both practical and conceptual difficulties in undertaking research on the nutritional needs of the very old and in making recommendations with wide applicability. In particular, there is limited understanding of, or agreement about, the outcomes measures which might be used as criteria for assessing nutritional adequacy in this population group. One would anticipate that measures of function will be the most informative outcomes but which functions should be measured? Most physical and cognitive functions decline with age with great inter-individuality in the rate of decline which creates both difficulties, and opportunities, when defining and assessing markers of healthy ageing[76,77]. Further, the relationships between (biomarkers of) function and health outcomes can be very different among the very old compared with their younger counterparts. For example, whilst high blood pressure is a well-established risk factor for CVD and for premature mortality among younger adults, this relationship is not seen in those aged 85+ years[78]. Indeed, among men and women aged >80 years (mean 87·6 years) resident in nursing homes, low blood pressure was associated with higher mortality[79]. Higher blood pressure is associated with improved cognitive function[80] and, in a prospective analysis within the Newcastle 85+ study, lower systolic blood pressure was associated with greater cognitive impairment and higher risk of disability[61].

Conclusion

Future guidelines on the nutritional needs of older people may benefit from more personalised, or stratified, approaches[81] which derive individualised recommendations using information on individual phenotype, including chronic disease and disability, exposure to prescribed and other medications and physical activity, in addition to the conventional variables of sex and age. This would require a radical shift from the current static tables of nutritional needs to more dynamic, digital-based technologies. Such approaches would be based on algorithms that use information about the individual and his/her circumstances to generate personalised nutritional requirements. From there it would be a relatively small step to extend such personalisation so that the digital platform could provide suggestions for foods/meals and DP which deliver the individual's nutritional requirements. The latter approach could take into account factors such as food preferences, dentition and limitations, if any, in ability to source, prepare and cook foods so that the proffered solution has maximum applicability.

Such a radical change in the way that nutritional needs are conceptualised and the tools for determination of individualised needs are developed is predicated on a substantial increase in research on the nutrition of older people. This sharpened focus on older people aligns well with the research strategies of funding agencies in most of the economically developed world where population ageing and its associated burden of ill-health are driving innovation in both basic and applied research to facilitate greater health and wellbeing in later life. The ideas offered here may help to identify key evidence gaps and to inform the development of subsequent research strategies.

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Conflict of Interest

None.

Authorship

T. R. H. presented the work and was responsible for the conception of the manuscript. T. R. H., N. M., A. J. A., J. C. M., A. G., C. J. S., M. S. and C. J. researched and prepared sections for the manuscript. All authors reviewed the manuscript prior to submission.

References

1. European Commission (DG ECFIN) and Economic Policy Committee (Ageing Working Group) (2015) The 2015 Ageing Report: Economic and Budgetary Projections for the 28 EU Member States (2013–2060). European Economy, no. 3.
2. Wanless D, Forder J, Poole T *et al.* (2006) *Wanless Social Care Review: Securing Good Care for Older People: Taking a Long-term View*. London: King's Fund.
3. Brownie S (2006) Why are elderly individuals at risk of nutritional deficiency? *Int J Nurs Pract* **12**, 110–118.
4. Siervo M, Prado C, Hooper L *et al.* (2015) Serum osmolarity and haematocrit do not modify the association between the impedance index (Ht(2)/Z) and total body water in the very old: the Newcastle 85+ study. *Arch Gerontol Geriatr* **60**, 227–232.
5. Di Francesco V, Fantin F, Omizzolo F *et al.* (2007) The anorexia of aging. *Dig Dis* **25**, 129–137.
6. Beasley JM, Shikany JM & Thomson CA (2013) The role of dietary protein intake in the prevention of sarcopenia of aging. *Nutr Clin Pract* **28**, 684–690.
7. Methven L, Allen VJ, Withers CA *et al.* (2012) Ageing and taste. *Proc Nutr Soc* **71**, 556–565.
8. Boltong A & Keast R (2012) The influence of chemotherapy on taste perception and food hedonics: a systematic review. *Cancer Treat Rev* **38**, 152–163.
9. Halford JCG, Harrold JA, Lawton CL *et al.* (2005) Serotonin (5-HT) Drugs: effects on Appetite Expression and Use for the Treatment of Obesity. *Curr Drug Targets* **6**, 201–213.
10. Akamine D, Filho MK & Peres CM (2007) Drug-nutrient interactions in elderly people. *Curr Opin Clin Nutr Metab Care* **10**, 304–310.
11. Granic A, Aspray T, Hill T *et al.* (2014) 25-hydroxyvitamin D and increased all-cause mortality in very old women: the Newcastle 85+ study. *J Intern Med* **277**, 456–467.
12. Granic A, Hill TR, Kirkwood TB *et al.* (2015) Serum 25-hydroxyvitamin D and cognitive decline in the very old: the Newcastle 85+ study. *Eur J Neurol* **22**, 106–115, e6–7.
13. Barnard K & Colon-Emeric C (2010) Extraskeletal effects of vitamin D in older adults: cardiovascular disease, mortality, mood, and cognition. *Am J Geriatr Pharmacother* **8**, 4–33.
14. O'Leary F & Samman S (2010) Vitamin B12 in health and disease. *Nutrients* **2**, 299–316.
15. Van der Zwaluw NL, Dhonukshe-Rutten RA, van Wijngaarden JP *et al.* (2014) Results of 2-year vitamin B treatment on cognitive performance: secondary data from an RCT. *Neurology* **83**, 2158–2166.
16. Collerton J, Davies K, Jagger C *et al.* (2009) Health and disease in 85 year olds: baseline findings from the Newcastle 85+ cohort study. *BMJ* **339**, b4904.
17. Collerton J, Barrass K, Bond J *et al.* (2007) The Newcastle 85+ study: biological, clinical and psychosocial factors associated with healthy ageing: study protocol. *BMC Geriatr* **7**, 1410.
18. Davies K, Kingston A, Robinson L *et al.* (2014) Improving retention of very old participants in longitudinal research: experiences from the Newcastle 85+ Study. *PLoS ONE* **9**, e108370.
19. Wham CA, Teh R, Moyes S *et al.* (2015) Health and social factors associated with nutrition risk: Results from life and living in advanced age: a cohort study in New Zealand (LILACS NZ). *J Nutr Health Aging* **19**, 637–645.
20. Wham C, Baggett F, Teh R *et al.* (2015) Dietary protein intake may reduce hospitalisation due to infection in Mori of advanced age: LiLACS NZ. *Aust N Z J Public Health* **39**, 390–395.
21. Teh R, Kerse N, Kepa M *et al.* (2014) Self-rated health, health-related behaviours and medical conditions of Maori and non-Maori in advanced age: LiLACS NZ. *N Z Med J* **127**(1397), 13–29.
22. Dyall L, Kepa M, Teh R *et al.* (2014) Cultural and social factors and quality of life of Maori in advanced age. Te puawaitanga o nga tapuwae kia ora tonu - Life and living in advanced age: a cohort study in New Zealand (LiLACS NZ). *N Z Med J* **127**, 62–79.
23. Teh R, Doughty R, Connolly M *et al.* (2013) Agreement between self-reports and medical records of cardiovascular disease in octogenarians. *J Clin Epidemiol* **66**, 1135–1143.
24. Dyall L, Kepa M, Hayman K *et al.* (2013) Engagement and recruitment of Mori and non-Mori people of advanced age to LiLACS NZ. *Aust N Z J Public Health* **37**, 124–131.
25. Hayman KJ, Kerse N, Dyall L *et al.* (2012) Life and living in advanced age: a cohort study in New Zealand- Te Puawaitanga o Nga Tapuwae Kia Ora Tonu, LiLACS NZ: study protocol. *BMC Geriatr* **12**, 33.
26. Beckmann M, Lloyd A, Haldar S *et al.* (2013) Dietary exposure biomarker-lead discovery based on metabolomics analysis of urine samples. *Proc Nutr Soc* **72**, 352–361.
27. Finch SDW, Lowe C, Bates CJ *et al.* (1998) *National Diet and Nutrition Survey: People Aged 65 Years and Over*. London: The Stationery Office.
28. Henderson L, Gregory J & Swan G (2003) *The National Diet and Nutrition Survey: Adults Aged 19 to 64 Years - Vitamin and Mineral Intake and Urinary Analytes*. London: The Stationery Office.
29. Nelson M, Erens B, Bates B *et al.* (2007) *Low Income Diet and Nutrition Survey*. London: The Stationery Office.
30. Davis RE, Couper MP, Janz NK *et al.* (2010) Interviewer effects in public health surveys. *Health Educ Res* **25**, 14–26.
31. Langhaug LF, Cheung YB, Pascoe SJ *et al.* (2011) How you ask really matters: randomised comparison of four sexual behaviour questionnaire delivery modes in Zimbabwean youth. *Sex Transm Infect* **87**, 165–173.
32. Biró G, Hulshof KFAM, Ovesen L *et al.* (2002) Selection of methodology to assess food intake. *Eur J Clin Nutr* **56** Suppl. 2, S25–S32.
33. Johnson RK, Driscoll P & Goran MI (1996) Comparison of multiple-pass 24-hour recall estimates of energy intake with total energy expenditure determined by the doubly labeled water method in young children. *J Am Diet Assoc* **96**, 1140–1144.
34. Adamson AJ, Collerton J, Davies K *et al.* (2009) Nutrition in advanced age: dietary assessment in the Newcastle 85+ study. *Eur J Clin Nutr* **63** Suppl. 1, S6–S18.
35. The EPIC-Oxford Study. Available at: http://www.epic-oxford.org/ (cited 15/01/2015).
36. Ocke MC, Buurma-Rethans EJM, de Boer EJ *et al.* (2013) Diet of community-dwelling older adults: Dutch National Food Consumption Survey Older adults 2010–2012. Rijksinstituut voor Volksgezondheid en Milieu RIVM.
37. Bartali B, Salvini S, Turrini A *et al.* (2003) Age and disability affect dietary intake. *J Nutr* **133**, 2868–2873.
38. Volkert D, Kreuel K, Heseker H *et al.* (2004) Energy and nutrient intake of young-old, old-old and very-old elderly in Germany. *Eur J Clin Nutr* **58**, 1190–1200.
39. Fabian E & Elmadfa I (2008) Nutritional situation of the elderly in the European Union: data of the European Nutrition and Health Report (2004). *Ann Nutr Metab* **52** Suppl. 1, 57–61.
40. Mendonça N, Hill TR, Granic A *et al.* (2016) Macronutrient intake and food sources in the very old: analysis of the Newcastle 85+ Study. *Br J Nutr* (In the Press).

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41. Mendonça N, Hill TR, Granic A *et al.* (2015) Micronutrient intake and food sources in the very old. *Proc Nutr Soc* **74**(OCE4).
42. Devlin UM, McNulty BA, Nugent AP *et al.* (2012) The use of cluster analysis to derive dietary patterns: methodological considerations, reproducibility, validity and the effect of energy mis-reporting. *Proc Nutr Soc* **71**, 599–609.
43. Wirfält E, Drake I & Wallström P (2013) What do review papers conclude about food and dietary patterns? *Food Nutr Res* **57**, 1–14.
44. Liese AD, Krebs-Smith SM, Subar AF *et al.* (2015) The dietary patterns methods project: synthesis of findings across cohorts and relevance to dietary guidance. *J Nutr* **145**, 393–402.
45. Allès B, Samieri C, Féart C *et al.* (2012) Dietary patterns: a novel approach to examine the link between nutrition and cognitive function in older individuals. *Nutr Res Rev* **25**, 207–222.
46. Siervo M, Lara J, Chowdhury S *et al.* (2015) Effects of the dietary approach to stop hypertension (DASH) diet on cardiovascular risk factors: a systematic review and meta-analysis. *Br J Nutr* **113**, 1–15.
47. Larsson SC, Akesson A & Wolk A (2014) Healthy diet and lifestyle and risk of stroke in a prospective cohort of women. *Neurology* **83**, 1699–1704.
48. Wengreen H, Munger RG, Cutler A *et al.* (2013) Prospective study of Dietary Approaches to Stop Hypertension- and Mediterranean-style dietary patterns and age-related cognitive change: the Cache County Study on Memory, Health and Aging. *Am J Clin Nutr* **98**, 1263–1271.
49. Lourida I, Soni M, Thompson-Coon J *et al.* (2013) Mediterranean diet, cognitive function, and dementia. *Epidemiology* **24**, 479–489.
50. Reedy J, Krebs-Smith SM, Miller PE *et al.* (2014) Higher diet quality is associated with decreased risk of all-cause, cardiovascular disease, and cancer mortality among older adults. *J Nutr* **144**, 881–889.
51. Anderson AL, Harris TB, Tylavsky FA *et al.* (2011) Dietary patterns and survival of older adults. *J Am Diet Assoc* **111**, 84–91.
52. Willcox DC, Scapagnini G & Willcox BJ (2014) Healthy aging diets other than the Mediterranean: a focus on the Okinawan diet. *Mech Ageing Dev* **136–137**, 148–162.
53. Sofi F, Macchi C, Abbate R *et al.* (2013) Mediterranean diet and health status: an updated meta-analysis and a proposal for a literature-based adherence score. *Public Health Nutr* **17**, 2769–2782.
54. Slattery ML (2010) Analysis of dietary patterns in epidemiological researchThis paper is one of a selection of papers published in the CSCN–CSNS 2009 Conference, entitled Are dietary patterns the best way to make nutrition recommendations for chronic disease prevention? *Appl Physiol Nutr Metab* **35**, 207–210.
55. Kant AK (2004) Dietary patterns and health outcomes. *J Am Diet Assoc* **104**, 615–635.
56. Larrieu S, Letenneur L, Berr C *et al.* (2004) Sociodemographic differences in dietary habits in a population-based sample of elderly subjects: the 3C study. *J Nutr Health Aging* **8**, 497–502.
57. Conklin AI, Forouhi NG, Surtees P *et al.* (2014) Social relationships and healthful dietary behaviour: evidence from over-50s in the EPIC cohort, UK. *Soc Sci Med* **100**, 167–175.
58. Mullie P, Clarys P, Hulens M *et al.* (2010) Dietary patterns and socioeconomic position. *Eur J Clin Nutr* **64**, 231–238.
59. Granic A, Davies K, Adamson A *et al.* (2015) Dietary patterns and socioeconomic status in the very old: the Newcastle 85+ study. *PLoS ONE* **10**, e0139713.
60. Reynolds JR & Ross CE (1998) Social stratification and health: education's benefit beyond economic status and social origins. *Soc Probl* **45**, 221–247.
61. Martin-Ruiz C, Jagger C, Kingston A *et al.* (2011) Assessment of a large panel of candidate biomarkers of ageing in the Newcastle 85+ Study. *Mech Ageing Dev* **132**, 496–502.
62. Hill TR, Granic A, Davies K *et al.* (2016) Serum 25-hydroxyvitamin D concentration and its determinants in the very old: the Newcastle 85+ Study. *Osteoporos Int* **27**, 1199–1208.
63. Mathei C, Van Pottelbergh G, Vaes B *et al.* (2013) No relation between vitamin D status and physical performance in the oldest old: results from the Belfrail Study. *Age Ageing* **42**, 186–190.
64. Bruyere O, Slomian J, Beaudart C *et al.* (2014) Prevalence of vitamin D inadequacy in European women aged over 80 years. *Arch Gerontol Geriatr* **59**, 78–82.
65. Cashman KD, Wallace JM, Horigan G *et al.* (2009) Estimation of the dietary requirement for vitamin D in free-living adults >=64 y of age. *Am J Clin Nutr* **89**, 1366–1374.
66. NatCen Social Research, MRC Human Nutrition Research, University College London (2014) National Diet and Nutrition Survey Years 1–4, 2008/2009–2010/12 – Appendices and Tables.
67. Jackson AS, Janssen I, Sui X *et al.* (2012) Longitudinal changes in body composition associated with healthy ageing: men, aged 20–96 years. *Br J Nutr* **107**, 1085–1091.
68. Siervo M & Jebb SA (2010) Body composition assessment: theory into practice: introduction of Multicompartment models. *IEEE Eng Med Biol Mag* **29**, 48–59.
69. Prado CM, Wells JC, Smith SR *et al.* (2012) Sarcopenic obesity: a critical appraisal of the current evidence. *Clin Nutr* **31**, 583–601.
70. Fielding RA, Gunstad J, Gustafson DR *et al.* (2013) The paradox of overnutrition in aging and cognition. *Ann N Y Acad Sci* **1287**, 31–43.
71. van den Berg E, Biessels GJ, de Craen AJ *et al.* (2007) The metabolic syndrome is associated with decelerated cognitive decline in the oldest old. *Neurology* **69**, 979–985.
72. Atti AR, Palmer K, Volpato S *et al.* (2008) Late-life body mass index and dementia incidence: nine-year follow-up data from the Kungsholmen project. *J Am Geriatr Soc* **56**, 111–116.
73. Harrison SL, Stephan BC, Siervo M *et al.* (2015) Is there an association between metabolic syndrome and cognitive function in very old adults? The Newcastle 85+ Study. *J Am Geriatr Soc* **63**, 667–675.
74. Siervo M, Kingston A, Kirkwood T *et al.* (2014) Anthropometric measures of adiposity as predictors of disability-free life expectancy and all-cause mortality in the very-old. *Gerontologist* **54**, 26.
75. Scientific Advisory Committee on Nutrition (SACN) (2011) *Dietary Reference Values for Energy*. London: Public Health England.
76. Lara J, Godfrey A, Evans E *et al.* (2013) Towards measurement of the healthy ageing phenotype in lifestyle-based intervention studies. *Maturitas* **76**, 189–199.
77. Lara J, Cooper R, Nissan J *et al.* (2015) A proposed panel of biomarkers of healthy ageing. *BMC Med* **13**, 222.
78. van Bemmel T, Woittiez K, Blauw GJ *et al.* (2006) Prospective study of the effect of blood pressure on renal function in old age: the Leiden 85-Plus Study. *J Am Soc Nephrol* **17**, 2561–2566.
79. Benetos A, Labat C, Rossignol P *et al.* (2015) Treatment with multiple blood pressure medications, achieved

blood pressure, and mortality in older nursing home residents: The PARTAGE Study. *JAMA Intern Med* **175**, 989–995.
80. Euser SM, van Bemmel T, Schram MT *et al.* (2009) The effect of age on the association between blood pressure and cognitive function later in life. *J Am Geriatr Soc* **57**, 1232–1237.
81. Celis-Morales C, Lara J & Mathers JC (2015) Personalising nutritional guidance for more effective behaviour change. *Proc Nutr Soc* **74**, 130–138.